§37. Study on Impurity Effects to Hydrogen Isotope Retention Behavior in Impurity-containing Boron Films

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i) Introduction

For deuterium plasma experiment in LHD, it is important to estimate the retention behavior of hydrogen isotope, including tritium in boron film produced by boronization, from the view point of tritium inventory control.

In previous study, it was clarified that the hydrogen isotope retention trapped by impurity in carbon-oxygen containing boron film was larger than only carbon or oxygen contained one even in the same impurity concentration., suggesting that the hydrogen retention trapped by impurity was enhanced by the co-existence of carbon and oxygen impurities in boron film. In this study, hydrogen retention in boron film under actual environment was estimated by consideration of the relationship between the chemical state and hydrogen retention about boron film exposed to hydrogen plasma in LHD.

ii) Experimental

Boron films prepared by the boronization in LHD onto silicon substrate were used. These samples were preheated at 1173 K for 10 minutes to remove the hydrogen implanted by boronization. These samples were introduced in LHD by the 4.5L port and exposed to 94 shots of hydrogen plasma. The depth profile of chemical state of boron and impurity was estimated by means of X-ray Photoelectron Spectroscopy (XPS). The hydrogen isotope retention behavior was estimated by Thermal Desorption Spectroscopy (TDS), respectively. TDS analysis was performed from room temperature to 1173 K with the heating rate of 0.5 K s^{-1}. In addition, the depth distribution of hydrogen was clarified by means of Glow Discharge - Optical Emission Spectroscopy (GD-OES) at Toyama University.

iii) Results and discussion

The XPS results showed that the chemical states for the LHD plasma exposed boron film were B-B bond, B-C bond, free oxygen and free carbon. In our previous study, it is known that B-B bond and B-C bond would be one of trapping sites of hydrogen. On the other hand, free oxygen and free carbon should be interacted with hydrogen to form water and hydrocarbons as the sputtered particles. After exposure to hydrogen plasma, the ratios of B-C bond and free oxygen were increased, but B-O bond was hardly formed in these samples. The figure shows the hydrogen retention estimated by chemical state and the hydrogen retention trapped as each state in boron film prepared at LHD. In addition, the implanted hydrogen was trapped by boron and impurity as B-H-B, B-H, B-C-H and B-O-H bonds, and the hydrogen retentions could be estimated as shown in the left plot of the figure. It was clarified that there was a correlation between the deuterium retention of each trapping site and the amount of B-B, B-O and B-C in impurity containing boron film. GD-OES results suggested that the hydrogen was migrated toward the depth of 30 nm with the concentration profile. From these results, the hydrogen retention in impurity-containing boron film was able to estimate by taking account both of the project range of hydrogen and of the amount of hydrogen for various chemical states. It can be concluded that the deuterium retention in boron film can be estimated by the chemical sate metamorphosed by deuterium plasma.

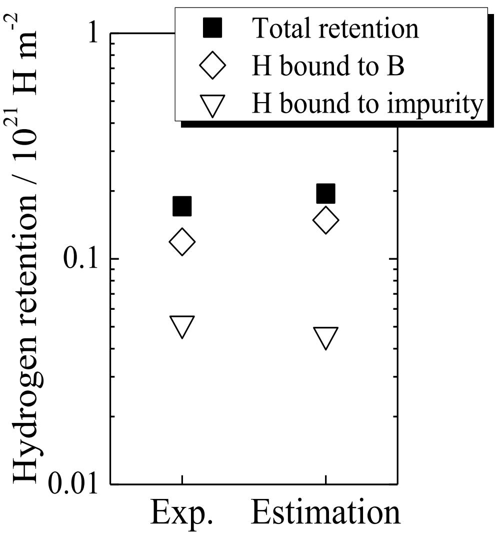

Fig. The hydrogen retention estimated by chemical state and the hydrogen retention trapped as each state in boron film formed at LHD